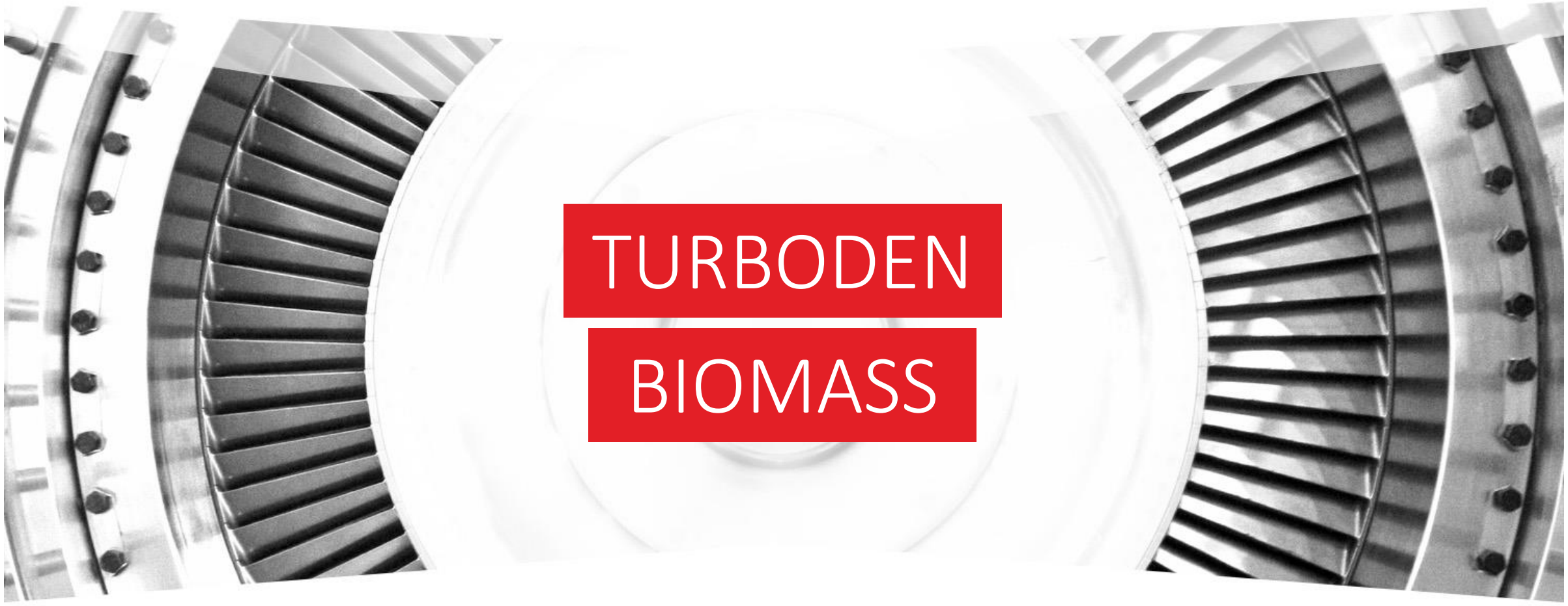
clean energy ahead
TURBODEN

MOVE THE WORLD FORWARD MITSUBISHI HEAVY INDUSTRIES GROUP



TURBODEN BIOMASS

Cod. 11-COM.P-1-rev.80

ORC COGENERATION SYSTEM FROM YOUR GREEN FUEL.

LEADER IN BIOMASS SINCE 1980

Since its foundation Turboden has been committed to delivering efficient and reliable cogeneration solutions from renewable sources.

ORC SYSTEM

Turboden Organic Rankine Cycle (ORC) plants produce electric power and heat with high efficiency and automatic operation by using any kind of biomass, from virgin wood to organic residues from various production processes.

KEY POINTS

- Large range size up to 20 MWe per single shaft
- Generate profit by valorizing a renewable source
- Provide a reliable source of power also for island mode operation
- Reduce specific production cost by decreasing energy demand
- Improve company sustainability
- Reduce CO_2 emissions

TURBODEN BIOMASS UNIT DESIGN

CHP SOLUTIONS (low and high temperature cogeneration)

Turboden units generate Combined Heat and Power (CHP) solution - providing either hot water or higher temperature heat medium (e.g. saturated steam or thermal oil). Alternatively Turboden can provide also electric power only solutions.

POWER-ONLY	CHP
Electrical efficiency up to 30%	Electrical efficiency up to 22%

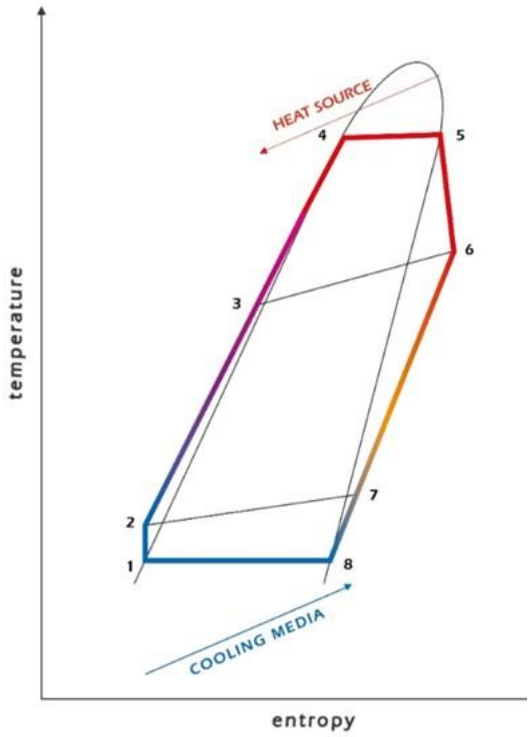
THE ORC CYCLE – HOW IT WORKS

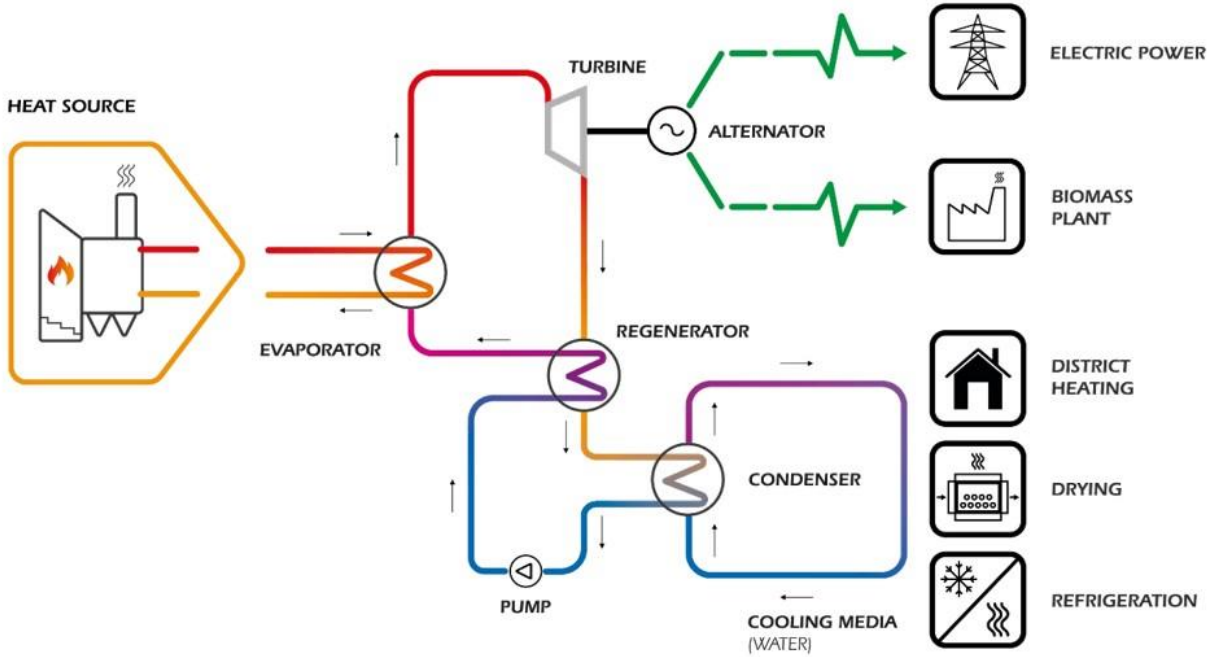
The ORC turbogenerator uses medium-to-high temperature thermal oil to preheat and vaporize a suitable organic working fluid in the evaporator (4>5).

The organic fluid vapor rotates the turbine (5>6), which is directly coupled to the electric generator, resulting in clean, reliable electric power.

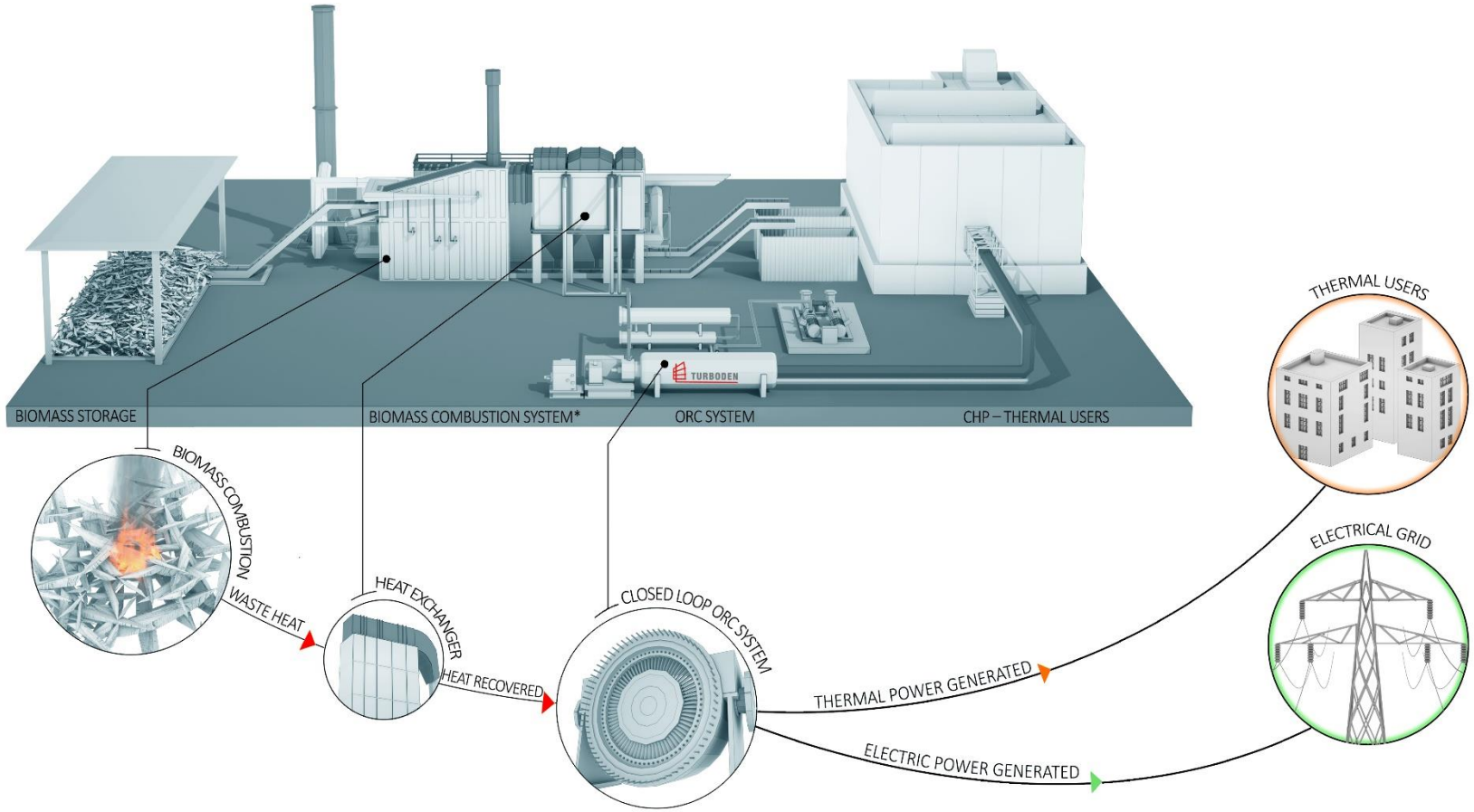
The exhaust vapor flows through the regenerator (6>7), where it heats the organic liquid (2>3) and is then condensed in the condenser and cooled by the cooling circuit (7>8>1).

The organic working fluid is then pumped (1>2) into the regenerator and evaporator, thus completing the closed-cycle operation.





EXAMPLE OF A BIOMASS PLANT WITH ORC SYSTEM

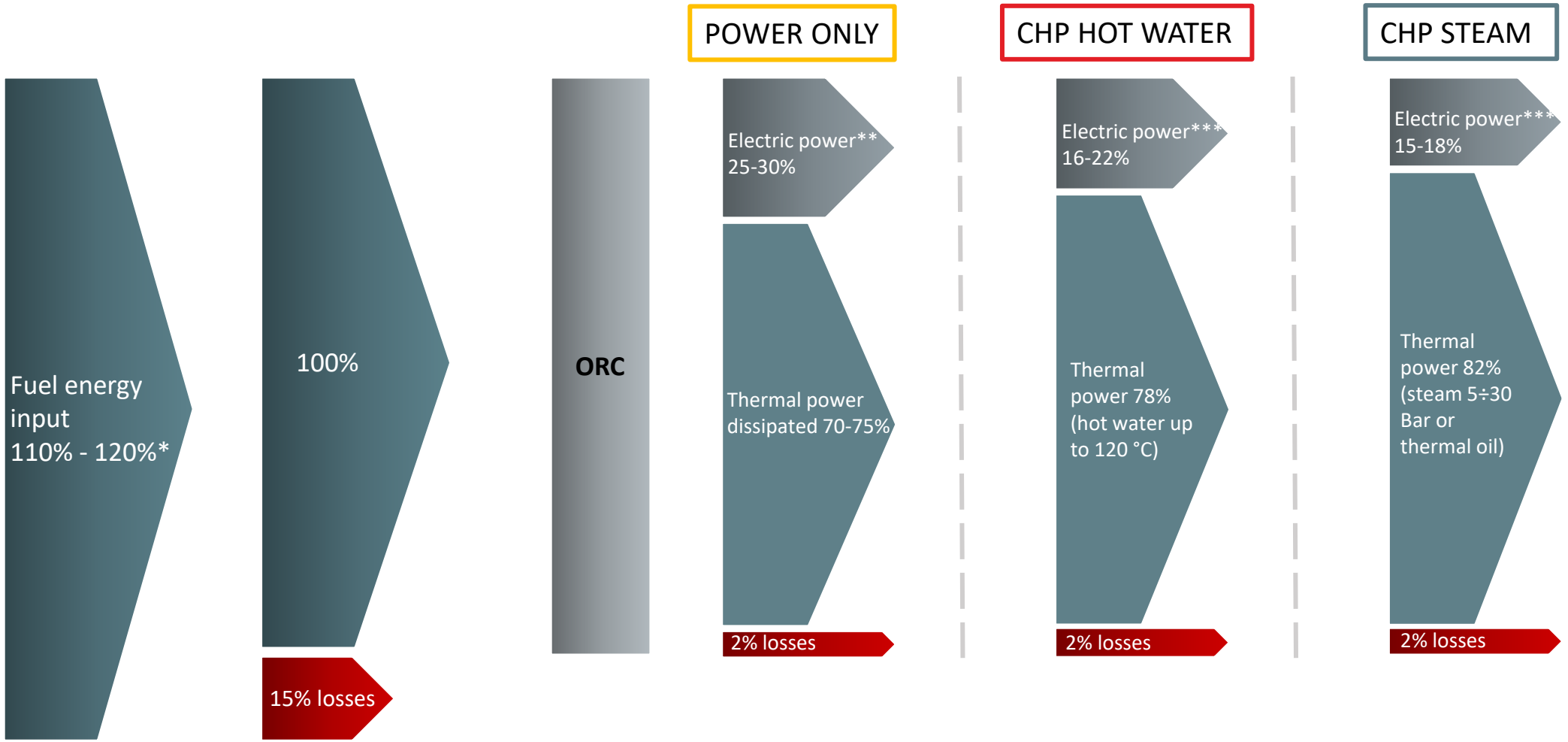


HEAT TRANSFER FLUID

The heat from biomass combustion is transferred to the ORC working fluid by means of an intermediate circuit or directly via the combustion gases in direct exchange systems. The media used in the intermediate circuits are thermal oil, saturated steam or superheated water.

*In alternative to more traditional combustion systems, gasification and pyrolysis solutions may be applied.

THREE MAIN POSSIBLE SCHEMES

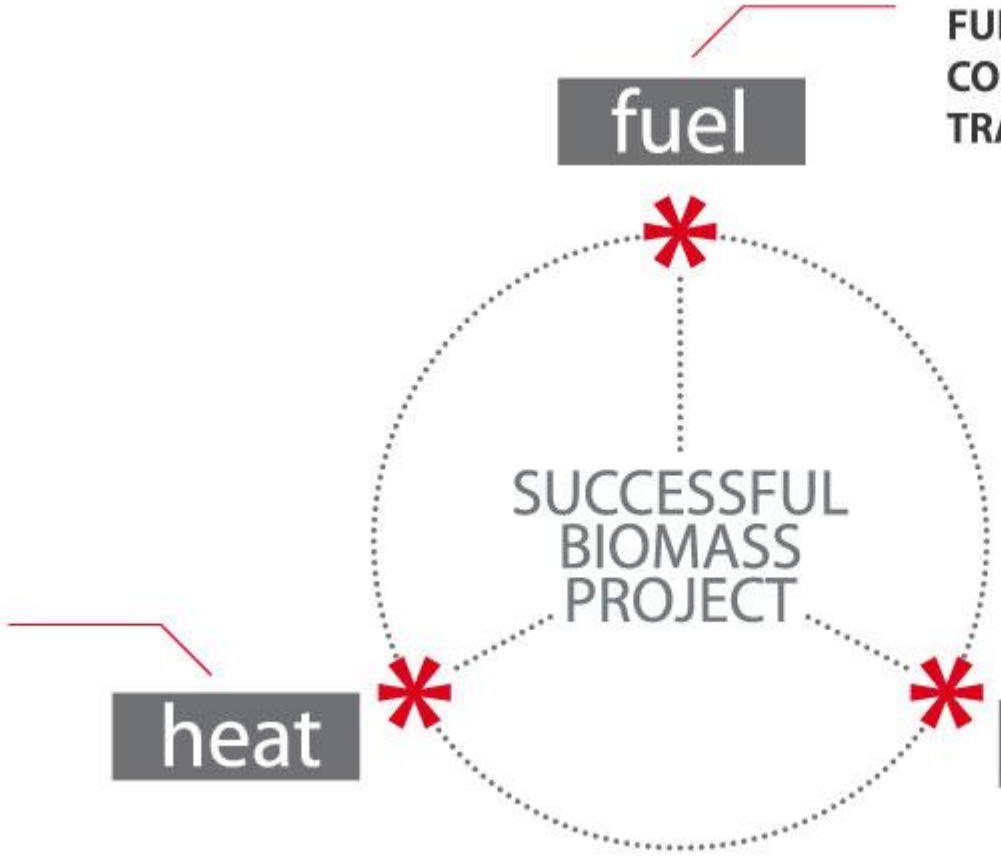


* Depending on fuel and boiler features

** Depending on size and environmental temperature

*** Depending on heat output temperature

KEY FACTORS FOR SUCCESS



FUEL AVAILABILITY AT AN AFFORDABLE COST IN THE LONG RUN MINIMIZING TRANSPORT COSTS

A HEAT USER TO VALORIZE THE CO-GENERATED HEAT (CHP configuration is more efficient and remunerative than a power-only one)

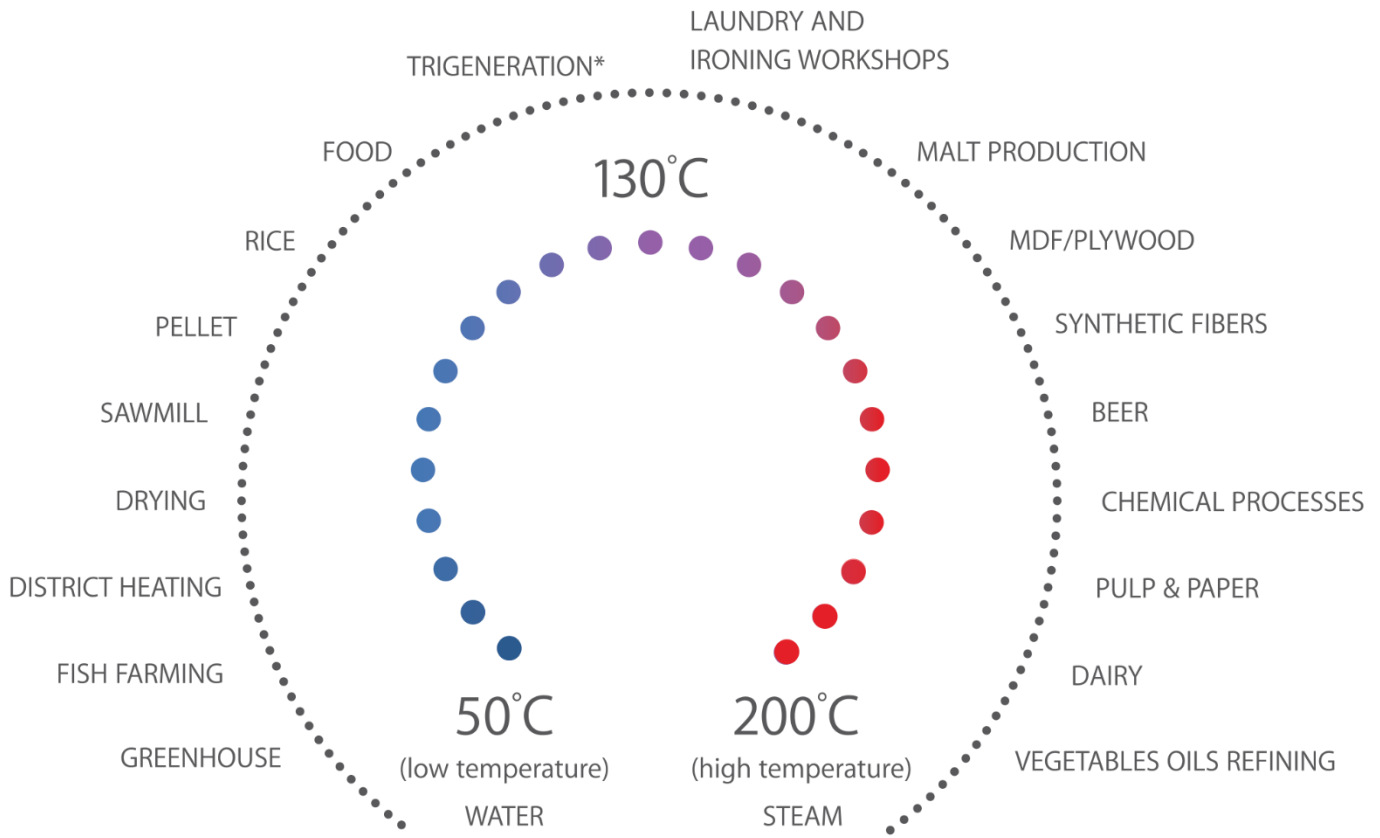
HIGH ENERGY VALUE (renewable incentives, PPA, feed-in tariffs, green certificates, etc.) **AND RELIABLE SOURCE OF ELECTRICITY IN ISLAND MODE SYSTEMS**

APPLICATIONS

TYPICAL FUELS

- sawmill residues or by-products
- bark
- wood dust and chips
- pellet
- furniture waste
- particle board screen dust
- recycled wood waste
- olive pomace and pits
- bruning & trimmings
- barley dust
- malt dust
- rice husks
- almond shells
- sunflower husks
- coffee husks and spent ground
- corn cobs
- coconut shells and husks
- empty fruit bunches
- palm kernel shells
- cotton gin waste, stalks
- paper

HEAT USERS



* with absorption chiller.

EXAMPLES OF SUCCESSFUL PROJECTS

	SAWMILL, WOOD-BASED PANEL	RICE, CEREALS, FOOD PROCESSING	DISTRICT HEATING	PELLET AND CHARCOAL PROD.	POWER ONLY
	91 plants	8 plants	167 plants	41 plants	20 plants
Fuel	Wood residues (e.g. bark, sawdust, etc.) from sawmill production process.	Rice husks, corn cobs, recovered locally from the rice/cereals processing industry.	Various depending on geographical area (typically wood chips).	Wood residues (e.g. bark, sawdust, etc.) from pellet and charcoal production process.	Various depending on geographical area.
Power	Used to feed internal auxiliaries; it can also be used to sustain island operation.	Used to feed internal auxiliaries; it can also be used to sustain island operation.	Incentives as a renewable source. Also used partly to power internal users.	Used to feed internal auxiliaries.	Incentives as a renewable source.
Heat	Fully used in drying chambers as hot water or low-pressure steam.	Used for rice processing as hot water or steam, cereal drying.	Used to feed the heating network.	Used as hot water for wood drying in the process.	No use.
Note	Fuel generated as by-product by the industry, heat and electricity valorized internally by the same industry.	Fuel produced as by-product by the facility, heat and electricity valorized internally by the same industry.	Fuel collected from various sources, heat sold to the local district heating network, electricity partly used internally, and the rest sold to the grid.	Fuel generated as by-product by the facility, heat and electricity valorized internally by the same industry.	Fuel collected from various sources, electricity sold to the grid. Business model viability subject to biomass price fluctuation.

CHP IN WOOD INDUSTRY

CUSTOMER:
Stia Holzindustrie

COUNTRY:
Austria

STATUS:
in operation since 1999

ORC SIZE:
0.5 MWe

DESCRIPTION:
CHP in a wood factory (wooden flooring and panels)

FUEL:
wood residues

HEAT CARRIER:
thermal oil

WATER TEMPERATURE (IN/OUT):
60 - 90 °C

Longest Turboden ORC in operation

More than 80 plants integrated with wood industries

POWER GENERATION IN SAWMILL

CUSTOMER:
West Fraser Mills

COUNTRY:
Canada

STATUS:
in operation since 2014 – 2015

ORC SIZE:
26 MWe (4 x 6.5 MWe)

DESCRIPTION:
power only in two large sawmills

FUEL:
residues from sawmill process (mainly bark)

HEAT CARRIER:
thermal oil

WATER TEMPERATURE (IN/OUT):
24 - 34°C

The largest lumber producer in North America

More than 80 **plants for** sawmills worldwide

CHP IN PELLET FACTORY

CUSTOMER:
Athens Energy

COUNTRY:
United States of America

STATUS:
in operation since October 2016

ORC SIZE:
8 MWe

DESCRIPTION:
power only in a wood pellet factory

FUEL:
virgin wood

HEAT CARRIER:
thermal oil

WATER TEMPERATURE (IN/OUT):
25 - 33 °C

The largest Turboden biomass ORC turbine

More than 40 plants for pellet industry worldwide

CHP IN WOOD-BASED PANEL INDUSTRY

CUSTOMER:
Starwood

COUNTRY:
Turkey

STATUS:
in operation since October 2016

ORC SIZE:
5.5 MWe

DESCRIPTION:
CHP in an MDF panels factory

FUEL:
panels residues and wood waste

HEAT CARRIER:
thermal oil

WATER TEMPERATURE (IN/OUT):
90 - 110 °C

ADDITIONAL FEATURES:
ORC turbine locally produced by Turboden Turkey

About 10 plants (CHP and power only solutions) in Turkey

Tailored solutions for MDF, particle board, plywood factories, etc.

CHP FOR DISTRICT HEATING NETWORK

CUSTOMER:
Fernheizwerk Toblach-Innichen

COUNTRY:
Italy

STATUS:
in operation since December 2003

ORC SIZE:
1.5 MWe

DESCRIPTION:
CHP for the district heating network

FUEL:
wood chips

HEAT CARRIER:
thermal oil

WATER TEMPERATURE (IN/OUT):
60 - 80 °C

Renewable energy for houses heating

166 total plants for district heating

POWER GENERATION IN AGRO FOOD INDUSTRY

CUSTOMER:
Rice Hull

COUNTRY:
California, USA

STATUS:
Under construction, expected start-up 2021

ORC SIZE:
3.6 MWe

DESCRIPTION:
Electric power only with air cooled condenser (no water consumption)

FUEL:
rice husk

HEAT CARRIER:
thermal oil

Different kind of fuels: rice, cereal, production waste, etc.

Profitable management of agro residues

POWER GENERATION IN AGRO FOOD INDUSTRY

CUSTOMER:
Sobono

COUNTRY:
The Philippines

STATUS:
in operation since December 2017

ORC SIZE:
5.5 MWe

DESCRIPTION:
CHP in a farm for cereals dryers

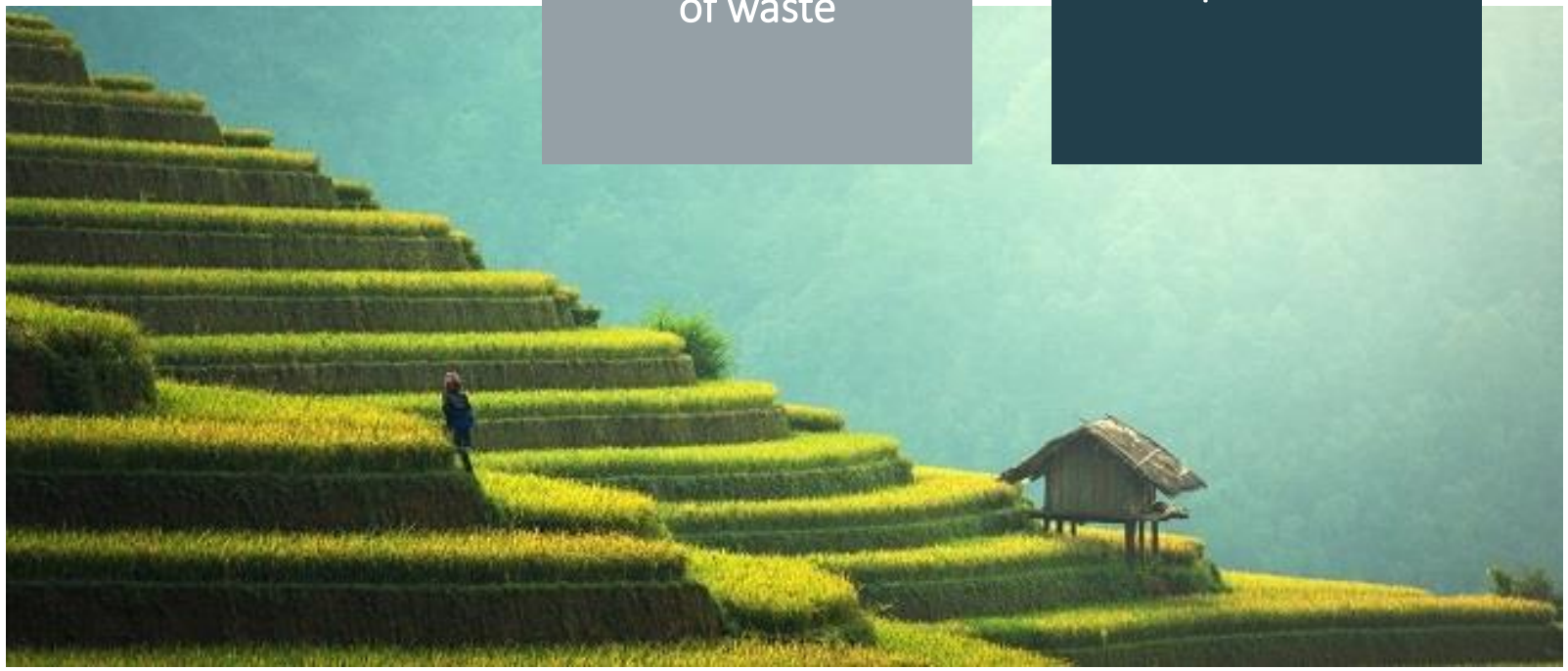
FUEL:
rice husk

HEAT CARRIER:
thermal oil

WATER TEMPERATURE (IN/OUT):
40 - 80 °C

Efficient exploiting of different kind of waste

Island mode operation



SELECTED CUSTOMERS

clean energy ahead TURBODEN

STARWOOD® ORMAN ÜRÜNLERİ SANAYİ A.Ş.

ITALIAN PANEL i-pan 100% POPLAR

West Fraser

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FIND OUT MORE

OUR EXPERIENCE. YOUR POWER.